WLAN (IEEE 802.11B) and WMAN (802.16A) Broadband Wireless Access: when opportunities drive solutions

Alberto Escudero-Pascual

Royal Institute of Technology, IMIT, S 164 40 Stockholm, Sweden
<aep@it.kth.se>

Abstract. The Institute of Electrical and Electronics Engineer (IEEE) approved in 1997 the Standard 802.11, followed by Standard 802.11b in 1999. Although the standards were intended for indoor wireless local area networks (WLAN), it took very little time to see WLAN-based products in point-to-point and point-to-multipoint outdoor solutions. The WLAN opportunity and its potencial benefits drove vendors and users to find innovative approaches to overcome the IEEE 802.11b native problems in outdoor environments. In April 2002, the IEEE Standard 802.16 was approved, a standard that focuses on broadband wireless access in metropolitan area networks (WirelessMAN). The new standard is expected to bring low cost and more bandwidth efficient products for broadband wireless access in the next years. Time will show what will be the final role of IEEE 802.11b in indoor and outdoor environments, but what we can not deny is the benefits and opportunities that provides today.

Introduction

The Institute of Electrical and Electronics Engineer (IEEE) 802.11b radio standard was approved in 1999, IEEE 802.11b was designed to operate in an indoor environment and delivers a maximum of 11 Mbps using Direct Sequence Spread Spectrum (DSSS) in the generally unlicensed Industrial, Scientific and Medical (ISM) 2.4 Ghz radio band.

Although it was initially conceived as a local area network wireless (WLAN) technology for indoor use and with clear output power restrictions, IEEE 802.11b is also currently being used for dedicated point-to-point (PtP) and point-to-multipoint (PtMP) radio links in metropolitan area networks (MAN) and rural areas.

The reasons for the fast deployment of IEEE 802.11b as part of basic data infrastructure can be found in the low cost of the radio equipment due to its mass production, the possibility of an easy integration with personal computers, the existence of a certified interoperability between vendors (Wi-Fi) or the existence of a very favorable regulatory framework in comparison with other radio technologies and related services.

It was not until April 2002, when a broadband wireless metropolitan area network (WirelessMAN, IEEE 802.16) standard from the Institute of Electrical and Electronics Engineers (IEEE) has been approved. IEEE 802.16 specifically addresses the "first-mile/last-mile" connection in wireless metropolitan area networks including requirements for interoperability in the Multipoint Microwave Distribution System (MMDS) and Local Multipoint Distribution System (LMDS) radio bands. The lack of accepted standards for MMDS and LMDS equipment has been one of the worst problems in terms of ensuring interoperability and keeping costs down.

IEEE 802.16 focuses on the efficient use of bandwidth between 10 and 66 GHz and defines a common medium access control (MAC) layer that supports multiple physical layer specifications customized for the frequency band of use. For example, the recently approved IEEE 802.16a standard is adapted to the 2 to 11 GHz region with PtMP and optional Mesh topologies.

However, it is natural to argue if it is a good idea to use IEEE 802.11b to implement long distance outdoor scenarios or different last-mile solutions. Other standards, as the recently approved IEEE 802.16a, has been specially designed for that purpose in mind (Wireless MAN) and optimized for multipath robustness by using a modulation technique known as Orthogonal Frequency Division Multiplexing (OFDM).

But, while IEEE 802.11b in conjunction with additional enhancing protocol extensions developed during recent years might not be the best solution for broadband wireless access from "technical" perspective, there are many other factors that still make worth considering IEEE 802.11b as a good technical and cost efficient alternative.

The hidden node problem in CSMA/CA

The IEEE 802.11 family standards as the IEEE 802.11b, IEEE 802.11g or IEEE 802.11a use (Time Division Duplexing (TDD)) media access scheme, operating half-duplex in a single shared frequency in where different time intervals are used for transmitting and reception. TDD differs from Frequency Division Duplexing (FDD), where different frequencies are used to carry upstream and downstream traffic simultaneously.

IEEE 802.11 includes Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) media access protocol as the basic mechanism to avoid simultaneous transmission (collisions) with other stations on the same channel. The IEEE 802.11 stations transmit only when the channel is not occupied. Since stations cannot detect a collision, access points must return an acknowledgment frame (ACK) to indicate successful receipt of data. A direct effect of the use of CSMA/CA is that effective throughput is lower than the channel's actual bandwidth (max. ~6 Mbps) because no other data can be sent while the ACK frames are using the channel.

In the case of a long range point-to-multipoint IEEE 802.11b scenario experiences also an additional overhead caused by the "hidden node" problem. When IEEE 802.11 stations can hear each other, they can sense when the channel is busy and use a back-off algorithm to avoid collision. However, in an outdoor environment it is common that the stations that can listen to a common access point not necessary can listen to each other and hence there is an increased probability of simultaneous transmission.

IEEE 802.11b includes as part of the standard a mechanism to prevent this problem, whenever a station has data to send, it can first issue a Request To Send (RTS) control frame. Upon RTS receipt, the access point allocates the corresponding time to the station and responds with a Clear To Send (CTS) control frame. Other stations may not hear the RTS, but can do avoid transmitting during the allocated time slot because all they can all hear the CTS coming from the access point that indicates the time that the channel is already reserved.

RTS/CTS in IEEE 802.11b PtMP outdoor networks

When using the RTS/CTS approach in an IEEE 802.11b outdoor point-to-multipoint network with many hidden nodes talking simultaneously and where stations are far apart, the "hidden node" problem occurs more often. The overhead due to RTS/CTS is bigger, RTS frames can also collide and the delays become significant when it comes to RTS/CTS time synchronizations. The time for arrival of the CTS frame to a hidden node is too big and unfortunately the RTS/CTS mechanism stops working efficiently when many clients are far away (>2 Kms) from the access point.

IEEE 802.16 standards take into consideration these specific problems when running PtMP radio links. Thus, the recent IEEE 802.16a standard includes built-in mechanisms to guarantee Quality of Service (QoS) in the link layer, better native encryption mechanisms, and deals with the hidden node problem using a combination of Time Division Multiplex Access (TDMA) and Demand Assigned Multiplex Access (DAMA) for the upstream traffic.

So, why is IEEE 802.11b still a possible solution worth considering? Because, while the IEEE 802.16 working group was discussing the wireless metropolitan area networks standard (e.g. IEEE 802.16a will be published by March 2003), vendors and users that were aware of the limitations of IEEE 802.11b have been developing innovative approaches to improve the performance in those outdoor environments.

Dynamic adaptive polling in IEEE 802.11b

An example of some of those extensions that are not part of the initial IEEE 802.11b standard and aim to solve the hidden node problem are Wave Wireless's SpeedLan access points [1] that use a proprietary CampusPRC protocol which polls stations for data and is configurable to support bandwidth allocation. Another solution comes from KarlNet's software that also implements a proprietary TurboCell [2] polling protocol that is already included in Agere Orinoco and Apple Airport products. Lately, Proxim has also announced their own IEEE 802.11b polling protocol (Wireless Outdoor Router Protocol (WORP)) as part of Tsunami MP.11 [3] and that in addition supports Asymmetric Bandwidth Throttling.

While the future of IEEE 802.16 (specially in the licensed-exempted radio spectrum part) is still unknown, many vendors have already put efforts into existing and well tested IEEE 802.11b radio products that have been quickly integrated in open architectures and performance and security has been instead enhanced by adding extra features in higher layers protocols (e.g. IP Bandwidth Control [4]).

Conclusion

Briefly, the basic IEEE 802.11b standard works well and is stable in dedicated long distance point-to-point links. In point-to-multipoint configurations with the presence of many active hidden nodes IEEE 802.11b needs to be enhanced with "polling extensions" to ensure good quality of service ("polling" is already part of the MAC Enhancements for QoS of IEEE 802.11e).

While the basic IEEE 802.11b might not be the best technical solution for the last-mile solution in dense Metropolitan Area Networks in comparison with the possibilities of the future of interoperable IEEE 802.16 products, IEEE 802.11b is the most cost-effective solution of today.

Some of the reasons have been already mentioned: the low cost of IEEE 802.11b products, the possibility to run those solutions in the unlicensed 2.4 Ghz ISM radio band, the existence of enhancements for IEEE 802.11b for the “hidden node” problem and the huge amount of collective experience.

The future of IEEE 802.16 looks promising and hopefully it will bring open standards, MMDS and LDMS interoperability and bandwith efficiency to the licensed and unlicensed Broadband Wireless Arena following the example of IEEE 802.11b. In an ideal world, we will see low cost dual radios with integrated OFDM-based standards as IEEE 802.11a or IEEE 802.11g with IEEE 802.16.

The way that users and vendors have adopted IEEE 802.11b reminds me how personal computers have been driving the open architecture revolution. One open question still remains: are we living the wireless one?

About the author

Alberto Escudero-Pascual is researcher at the Royal Institute of Technology since 1999. In 2002 he obtained his PhD in the area of privacy in the next generation Internet. Since his arrival to Sweden, Escudero has been involved in design and deployment of different wireless initiatives including the KTH/SU IT University wireless infrastructure(2000), a broadband wireless access in the city of Nora (2001) and the neutral access network StockholmOpen (2002).
More info at: `http://www.it.kth.se/~aep`

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